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Testing the simultaneous influence of three variables on the displacement in the Poggendorff figure

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TESTING THE SIMULTANEOUS INFLUENCE OF THREE VARIABLES ON THE DISPLACEMENT IN THE POGGENDORFF FIGURE

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A Thesis Presented to the Faculty of
the College of Optometry,
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INTRODUCTION

1. THE POGGENDORFF FIGURE

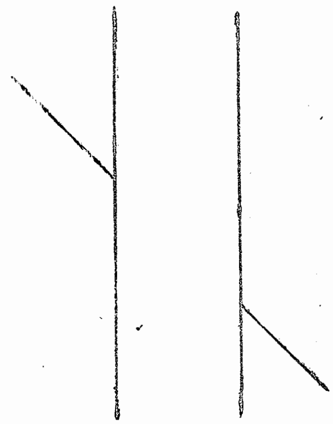

Figure 1.

Whenever an oblique line is interrupted by two parallel lines, a displacement is seen. The present paper tests some variables which may influence the displacement.

2. THE STATISTICAL APPROACH

The statistical treatment followed Fisher's analysis of variance. Thus it was possible to test the influence of three variables simultaneously. These variables are the angle, the length of line, and the subject.

THE EXPERIMENT

1. THE PROBLEM

To test the main effects and interactions of the three variables, subjects, lengths of angle side, angles, on the displacement in the Poggendorff figure.

2. THE MATERIAL

Instead of an apparatus that would allow an adjustment like Burmester's, a number of drawings were used.

The parallel lines were vertical, and the distance between the parallels was constant at 40 mm. Four angles were used: A_1 20°, A_2 40°, A_3 60° A_4 80°.

The length of the crossing oblique line showed the following proportions to the distance between the parallels: B_1 $\frac{1}{2}$, B_2 1, B_3 $1\frac{1}{2}$, B_4 2. Figure 2 shows three varations of the Poggendorff figure, White used (a), Johnson and Furie used (b), and (c) was the figure used in this experiment.

THREE VARATIONS OF THE POGGENDORFF FIGURE

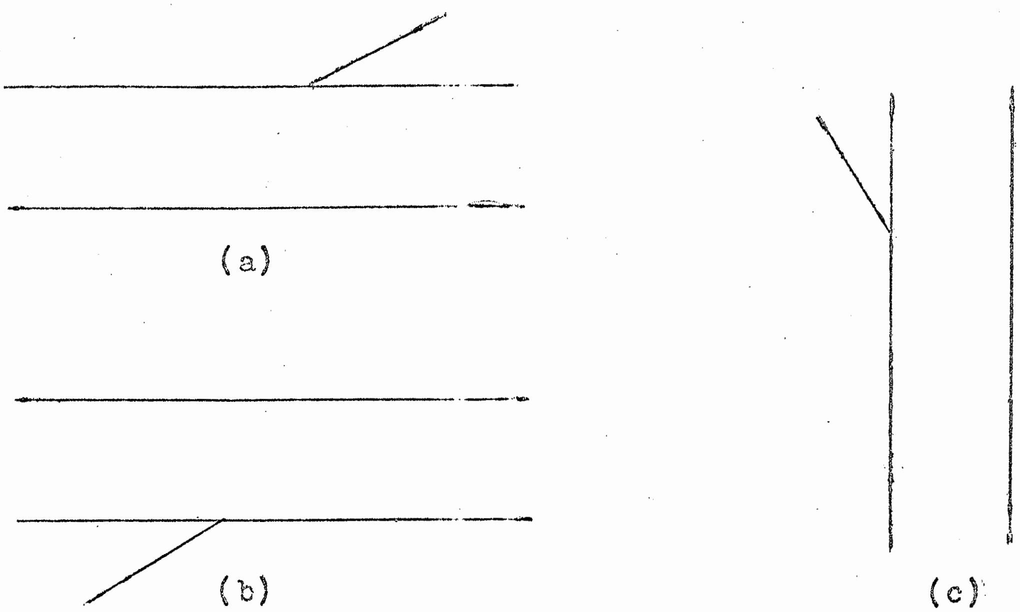

Figure 2

3. THE PROCEDURE

The procedure followed that given by White. Thus each subject observed each design five times. The sequence and order of the sixteen designs were randomized for each observer for each repetition.

4. THE INSTRUCTION

The observer was instructed to mark where a continuation of the oblique would cross if it were extended.

5. THE SUBJECTS

Five observers who had no knowledge of the displacement volunteered as subjects. There were four men and one woman, two undergraduates in optometry and three graduates of optometry.

6. THE STATISTICAL METHOD

A three dimensional design was used, i.e., treatment (A) x treatment (B) x subject (S), according to Lindquist. (5, p. 237f). It was decided that the 5 per cent level of significance should be used.

7. THE DATA

The four Tables (I-IV) contain the mean displacements for the four angles for each length for each subject. Thus Table I shows the values obtained for angle 20°, Table II the values obtained for angle 40°, etc. Each cell within each table represents the mean displacement for five observations. Thus in Table I 16.5 is the mean displacement of five observations for length 20 mm at angle 20° for subject one. The sums of the means for all subjects at each length are also shown. The last row gives the sums for the squares of the same means.

TABLE I

VARIABLE A_1 FOR ALL SUBJECTS FOR ALL LENGTHS (B)

	B_1	B_2	B_3	B_4
S_1	16.5	21.3	32.0	24.3
S_2	30.0	30.5	34.6	35.4
S_3	27.7	25.2	26.6	25.5
S_4	26.9	31.7	26.4	20.2
S_5	18.6	15.1	17.6	11.2
ΣX	119.7	124.8	137.2	116.6
(ΣX^2)	3009.11	2432.28	3935.44	3027.38

S = subjects B_1 = 20 mm. B_2 = 40 mm. B_3 = 60 mm. B_4 = 80 mm. A_1 = angle 20° Each value is based on the mean of five observations.

TABLE II

VARIABLE A_2 FOR ALL SUBJECTS FOR ALL LENGHTS (B)

	B_1	B_2	B_3	B_4
S_1	12.3	12.2	14.0	9.3
S_2	20.3	15.0	12.1	11.7
S_3	11.6	11.1	10.4	11.3
S_4	6.8	5.4	9.5	5.4
S_5	15.6	9.7	4.5	5.2
ΣX	66.6	53.4	50.5	42.9
(ΣX^2)	987.54	620.30	561.07	407.27

S = subjects B_1 = 20 mm. B_2 = 40 mm. B_3 = 60 mm. B_4 = 80 mm. A_2 = angle 40° Each value is based on the mean of five observations.

TABLE III

VARIABLE A_3 FOR ALL SUBJECTS FOR ALL LENGTHS (B)

	B_1	B_2	B_3	B_4
S_1	5.6	6.9	6.0	5.4
S_2	9.8	8.1	8.2	6.2
S_3	10.7	10.9	8.1	6.0
S_4	2.3	2.5	3.2	2.4
S_5	9.4	9.2	8.1	7.0
ΣX	37.8	37.6	33.6	27.0
(ΣX^2)	335.54	322.92	244.70	158.36

S= subjects B_1 = 20 mm. B_2 = 40 mm. B_3 = 60 mm. B_4 = 80 mm. A_3 = angle 60° Each value is based on the mean of five observations.

TABLE IV

VARIABLE A_4 FOR ALL SUBJECTS FOR ALL LENGTHS (B)

	B_1	B_2	B_3	B_4
S_1	.9	1.0	.8	.8
S_2	1.1	1.1	1.8	1.6
S_3	2.0	2.2	1.4	.7
S_4	1.5	1.1	1.7	1.2
S_5	2.3	3.1	1.5	1.9
ΣX	7.8	8.5	6.2	7.2
(ΣX^2)	13.56	17.87	10.98	8.74

S = subjects B_1 = 20 mm. B_2 = 40 mm. B_3 = 60 mm. B_4 = 80 mm. A_4 = angle 80° Each value is based on the mean of five observations.

Table V shows the sums of the measurements for all angles and all lengths for each subject and the squares of these totals. Thus, 172.3 is the sum of the displacements for all stimulus situations for subject one, and the square of this sum is 29687.29.

TABLE V

SUMS FOR ALL SUBJECTS FOR ALL A FOR ALL B

	ΣX	$(\Sigma X)^2$
S_1	172.3	29687.29
S_2	227.5	51756.25
S_3	191.4	36633.96
S_4	148.2	21963.24
S_5	138.0	19044.00
TOTAL	877.4	159084.00

S-subjects X-sums of all values for each subject over all lengths and all angles.

On the basis of Tables I-IV the total variance was calculated and found to be 7370.18.

In Table VI, each value represents the measurements for all angles at each length for each subject.. Thus, the value 35.5 is the sum of all measurements at length B_1 for subject one. Tables VII and VIII are arranged in a similar manner. The sums over all subjects for each angle and each length are shown in Table VII, and the sums over all lengths for each subject at each angle are found in Table VIII.

TABLE VI

SUMS OVER ALL A

	B_1	B_2	B_3	B_4	$\sum X_S$
S_1	35.3	44.4	52.8	39.8	172.3
S_2	61.2	54.7	56.7	54.9	227.5
S_3	52.0	49.4	46.5	43.5	191.4
S_4	37.5	40.7	40.8	29.2	148.2
S_5	45.9	35.1	31.7	25.3	138.0
$\sum X_B$	231.9	224.3	228.5	192.7	877.4

S = subjects B = length n per cell = 4

TABLE VII

SUMS OVER ALL S

	A_1	A_2	A_3	A_4	$\sum X_B$
B_1	119.7	66.6	37.8	7.8	231.9
B_2	124.8	53.4	37.6	8.5	224.3
B_3	137.2	50.5	33.6	6.2	227.5
B_4	116.6	42.9	27.0	7.2	193.7
$\sum X_A$	498.3	213.4	136.0	29.7	877.4

B = length A = angle n per cell = 5

TABLE VIII

SUMS OVER ALL B

	A_1	A_2	A_3	A_4	$\sum X_S$
S_1	97.1	47.8	23.9	3.5	172.3
S_2	130.5	59.1	32.3	5.6	227.5
S_3	105.0	44.4	35.7	6.3	191.4
S_4	105.2	27.1	10.4	5.5	148.2
S_5	60.5	35.0	33.7	8.8	138.0
$\sum X_A$	498.3	213.4	136.0	29.7	877.4

S = subjects A = angle n per cell = 4

From the margins of these three tables the sums of the squares of the three main effects can be determined. The column headed $\sum X_S$ in Table VI permits the calculation of the sums of the squares between subjects, and the row headed $\sum X_B$ in the same table allows the calculation of the sums of the squares between the different lengths. No new information is given in Table VII column $\sum X_B$, but from $\sum X_a$ the sums of the squares between the different angles is calculated. The sums of the squares between the different subjects is 319.9. Between angles it is 6038.16 and between lengths 45.32. No further information regarding the main effect is given in Table VIII in column $\sum X_S$ and row $\sum X_A$.

From the cells, that means the individual values, shown in Tables VI-VIII, the three two-factor interactions, AB, AS BS, can be calculated, thus, the individual values in Table VI give the basis for the sum of the squares between the subjects and the lengths. This sum of the squares was found to be 91.50. By the same method, Table VII gives the basis for the sum of the squares between angles and length which was found to be 76.49, and from Table VIII the sum of the squares of the interaction between the subjects and the angles was calculated to be 579.85.

Finally, the sums of the squares of the triple interaction, ABS is obtained as the difference between the sum of the sums of the squares of A, B, S, AB, BS, and the total sum of the squares. The value for the sum of the squares of the triple interaction, or residual, was calculated to be 218.95.

8. THE RESULTS

The calculation of the results is based on Table IX which shows the source, the degrees of freedom, the sums of the squares, and the mean of the sums of the squares or mean squares. The mean square is found by dividing the sums of the squares by the degrees of freedom for each source. The F values for the mean effects are determined by dividing the mean squares of the main effects, for angles and lengths, by the mean squares of the corresponding two-factor interaction. The F value for each two-factor interaction is found by dividing the mean squares of each interaction by the triple interaction mean square.

TABLE IX SUMMARY TABLE

Source	df	ss	ms	F
A	3	6038.16	2012.72	41.65
B	3	45.32	15.11	1.98
S	4	319.91	79.98	
AB	9	76.49	8.50	1.40
AS	12	579.85	48.32	7.95
BS	12	91.50	7.63	1.25
ABS	36	218.95	6.08	
TOTAL	79	7370.18		

df- degrees of freedom, ss-sums of the squares, ms-mean squares F-F value

MAIN EFFECTS

The F value for the angles (A) is significant at better than the 5% level. Thus the observed displacement differs significantly for different angles.

The F value for the lengths of the lines is not significant. It is generally assumed that subjects differ significantly on almost any criterion scale. Therefore it is unnecessary to find the F value for S.

THE INTERACTIONS

Only one interaction, namely AS is significant at the 5% level. This means that the effect of the angles differs from subject. As the two other interactions, AB and BS do not reach the 5% level we conclude that the effects of the angles and the lengths are independent, and that the influence of the length has no effect on the displacement, this was to be expected.

9. THE DISCUSSION

In this experiment the crossing parallel lines were in a vertical position, whereas horizontal parallels were used in the two preceding studies. In spite of this difference the results obtained in the three papers agree. In all three the displacement differs significantly for the four angles tested and appears as a function which decreases as the angle increases. Likewise all studies show a significant interaction between angles and subjects. A graphic representation of the findings for the present study is given in figure 3, which is based on table VIII. It shows that for all subjects the displacement decreases as the angle changes from 20 to 40 to 60 to 80 degrees. Besides the graphs clearly demonstrate that the relation is of different slopes for the five subjects.

10. THE LIMITATIONS

In the present experiment only four variations of the angle were used, 20°, 40°, 60°, 80° and four variations in the length of the angle side 20, 40, 60, and 80 mm. The distance between the parallels was kept constant at 40 mm. Only one position of the Poggendorff figure was used with the parallel lines lying in the vertical position and the oblique line being at the upper left of the design.

11. THE SUGGESTIONS

It is suggested that further experimentation be carried on in the field of optical illusions to gain new insights into the problem of how people react differentially to varing visual stimuli. The effects of refractive variables could be tested by having subject observe with and without the refractive errors being corrected Also the head tilt could be ridgedly controlled by the use of a head rest.

THE SUMMARY

Tested in this experiment were the main effects and interactions of the three variables, subject, length of line, and the angle on the displacement in the Poggendorff figure.

A number of drawings were used (see figure 2) . The observer was instructed to mark the right parallel where the oblique line would cross if it were extended.

A three dimensional design was used, i.e., treatment (A) by treatment (B) by subject (S). From the beginning it was decided to use the 5% level of significance.

It was found that there was only one variable significant at better than the 5% level, the angle. The lengths of the lines and two of the interactions were not significant at the 5% level.

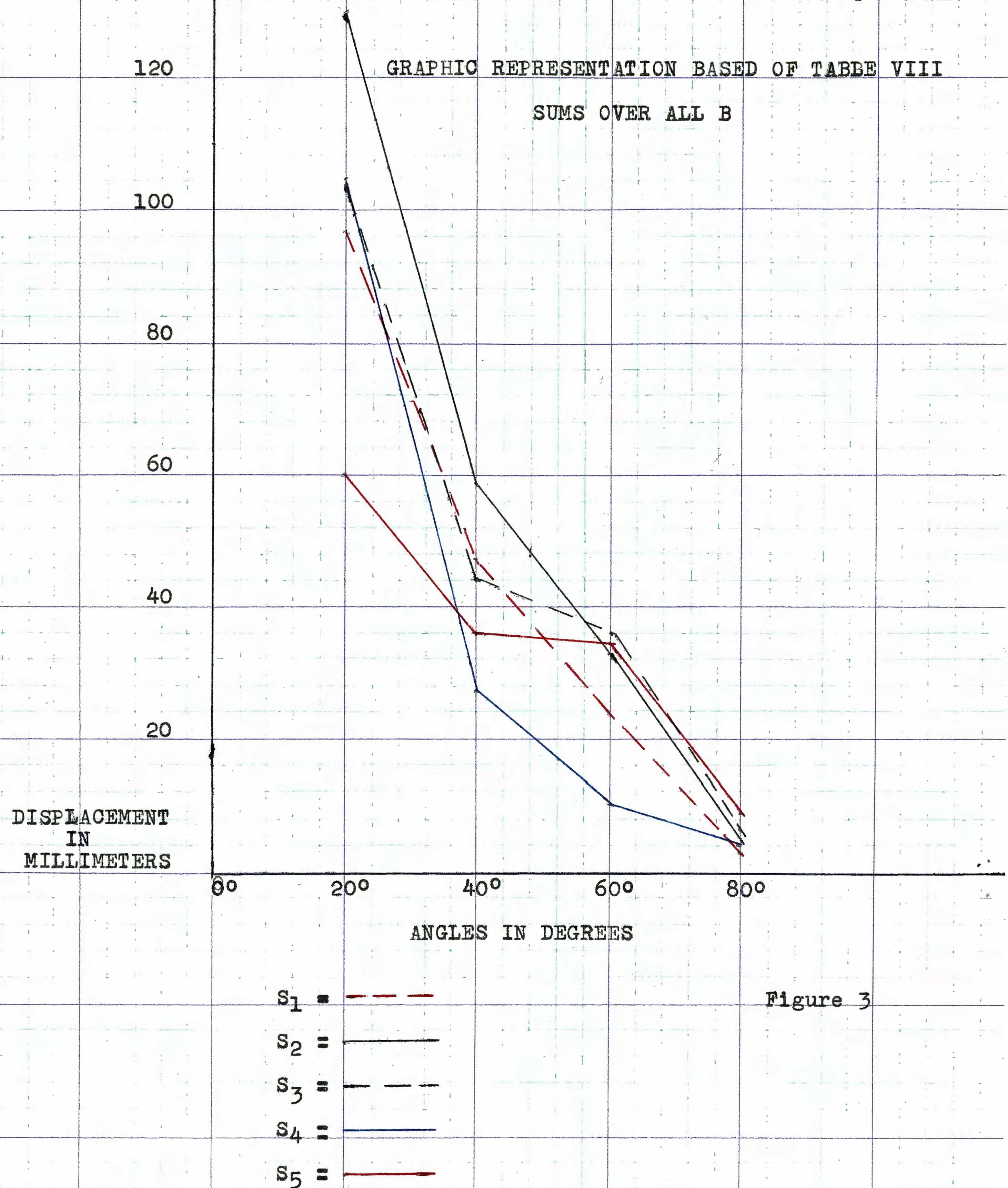
GRAPHIC REPRESENTATION BASED OF TABBE VIII
SUMS OVER ALL B
120
100
80
60
40
20
DISPLACEMENT
IN
MILLIMETERS
0°
20°
40°
60°
80°
ANGLES IN DEGREES
S_1 =
S_2 =
S_3 =
S_4 =
S_5 =

Figure 3

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